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OF

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Inaugural Address of the President, at the 14th General Meeting of the American Institute of Electrical Engineers, Eliot, Me., July 26th, 1887.

THE PRECISION OF ELECTRICAL ENGINEERING.

BY FRANCIS B. CROCKER.

There still exists quite a general idea that electricity is so imperfectly understood that its laws and actions are little more than matters of chance or guesswork. The experience of the electrical engineer is supposed to consist of a series of surprises and shocks to his mind as well as to his body. This notion is not confined to the ignorant, but is believed by many educated persons, even including our brother civil and mechanical engineers; indeed, some members of our own profession hear this opinion expressed so often that they partly accept it as true, or at least they have no ready arguments with which to refute it.

The existence of this popular error concerning electricity is perfectly natural, and arises from the novelty of the subject and the fact that its development has been so great and so rapid that no one but a few specialists have been able to keep pace with it.

The subtlety, extreme rapidity of action, and the astonishing achievements of this modern agency make it appear most mysterious and occult in comparison with the ordinary forms of energy, such as heat and mechanical power. Possessing such transcendental powers, it is looked upon as something not only unknown, but unknowable, an irresponsible power for great good, or great evil. This idea has sometimes been the cause of actual harm to the progress of electrical engineering. The profession has been considered to be hardly legitimate, those who practised it being regarded as either wizards or charlatans, or a combination of the two. During the present year, the president of a large steam railroad system, on which electric propulsion is being tried, publicly expressed his opinion that electrical engineers know

little or nothing of their subject. In legal decisions in this country and abroad, judges have stated that electricity was so vaguely understood, that testimony concerning it was of no practical value.

It has also been held by many courts, that electricity being intangible, has no real existence, so that the tapping of current from the wires could hardly be considered as a theft, except in an imaginary sort of a way. The production of electrical energy in central stations has been decided by metaphysically inclined judges to be a totally different kind of business from the manufacture of gas. In point of fact, the differences are all in favor of the practical character of electricity. More useful operations can be performed by it; it can be more easily transmitted and distributed; the percentage of leakage is less, and its measurement is far more convenient and accurate.

The idea that "no one knows what electricity is, therefore we know practically nothing about it," is often expressed by those who want to excuse their own ignorance of the subject. They are glad to think that they are no more worse off in this respect than the rest of the world. Their deduction is quite natural, but is absolutely fallacious. While we must admit that we do not know the real nature of electricity, the same limitation of knowledge applies to all other fundamental facts. Gravitation is the most familiar of natural phenomena, yet we have no conception whatever of what it actually is. Our theories and mental pictures of the nature of electricity are much more definite than those concerning gravitation. In regard to the latter, little progress has been made since the time of Newton, while electrical knowledge has advanced and is now advancing with giant strides. There is every reason to believe that we shall "know what electricity is" and be able to explain the inherent mechanism by which electrical actions take place, before we understand how and why a stone is drawn to the earth. What we do know, however, are the laws of both electricity and gravitation, as well as the results that they produce, and it is very doubtful if our ability to control, measure and utilize these agencies would be improved even if we understood their exact nature. The laws and applications of hydraulics would be just as definite and successful even though the fact were not known, that water is composed of two atoms of hydrogen and one of oxygen. It is possible that methods of generating electricity may be advanced when its real character

is discovered, but it is not likely that this knowledge will greatly affect the methods of handling and using it.

The popular ignorance and doubt concerning electricity is rapidly disappearing in consequence of the remarkable results accomplished by it during the last ten or fifteen years, but it will not be out of place, I think, to consider at this time the remarkable exactness which electrical engineering has reached. A discussion of this question may serve to inform laymen who are not familiar with the facts, and may also be a matter of interest and satisfaction to ourselves. This profession has only very recently gained for itself a position of independence and equality among the branches of engineering, but it can now fairly claim to be an example for the others to follow, not only in the magnitude and rapidity of its results, but also in the exactness and certainty of its methods. Let us consider what are the principal facts upon which this strong claim it based.

The names connected with electrical science:—Gilbert, Franklin, Faraday, Ampere, Maxwell, Henry, Helmholtz, Kelvin, and a long list of other distinguished electricians, are not men whose ideas are vague or incorrect. Indeed, it is a significant fact that the ablest and most profound scientific men have been attracted by, and have performed some of their best work in the study of electricity.

The rapid progress of electrical science and its applications is an absolute proof of sure and exact knowledge. Uncertainty would necessarily cause delay, and error would involve repeated trials before success could be reached. The fact that the difficult arts of long-distance transmission of power, and electric traction have been developed to their present state of importance and success in about ten years, shows conclusively that electrical theories and designs agree very closely with the actual facts.

The great results accomplished by electrical engineering is probably its strongest claim. Many of these are so unique and astonishing that we still regard them with wonder even after we have become familiar with them. Among the most striking of these examples are the locating of faults on submarine cables, telephoning a thousand miles or more, transmitting power over one hundred miles, sending simultaneously a number of messages on the same wire, utilizing the power of Niagara, and producing the Röntgen ray. These and hundreds of other wonderful feats are not accomplished by chance, or by groping in the dark.

The close relationship between pure and applied electrical science is still another proof of the exactness and truth of both. If knowledge were complete, theory and practice would become identical. The agreement between theoretical and practical electricity is largely due to the small losses which occur in electrical apparatus and processes. Even quantities which correspond to friction in mechanics, such as electrical resistance and magnetic hysteresis, are capable of exact calculation. It is only the purely non-electrical factors, such as the friction of bearings and air resistance, that are uncertain in designing electrical machinery. The almost infinite rapidity of electrical action makes the time element so small that it can almost always be neglected. This greatly simplifies calculations and renders their results more accurate. The fact that there is only one kind or quality of electricity also gives definiteness to our ideas and calculations. With coal we must know its quality, including both its physical and chemical properties, in order to make even approximate calculations concerning it. In the case of steam, pressure and volume are not sufficient data; the amount of moisture or superheating must also be known. The most accurate methods of the physicist are not any too good nor beyond the reach of the electrical engineer, and they are often employed by him. A notable example of this is Lord Kelvin's work in connection with laying the Atlantic cable, which was undertaken at about the same time that he began to publish his essays on the vortex theory of matter. When Werner Siemens first built his self-exciting dynamos, he also constructed the sensitive galvanometers, used in the researches of his friend Helmholtz. It was Siemens, the electrical engineer, who gave his money and influence to the Reichsanstalt, an institution where the most accurate physical work is now being carried on.

A historical example of the agreement between electrical theory and fact is the brilliant work of Ampere, who gave to the world a beautiful and complete theory of electro-magnetism within a few days after he heard of its discovery by Oersted. The work of Maxwell is another great example of the power of the intellect to deal with electrical problems.

Hertz said, in regard to Maxwell's electro-magnetic theory of light: "It is impossible to study this wonderful theory without feeling as if the mathematical equations had an independent life and an intelligence of their own; as if they were wiser than our-

selves, indeed, wiser than their discoverer; as if they gave forth more than he had put into them. And this is not altogether impossible; it may happen when the equations prove to be more correct than their discoverer could with certainty have known."

It can hardly be admitted that there is anything in Maxwell's equations that he did not put into them, but the remarkable experimental corroboration of Maxwell's theories many years after they were evolved, shows that from a few fundamental truths almost the whole theory of electricity may be deduced.

This power to solve problems successfully by *a priori* reasoning demonstrates the perfection of electrical science. We can arrive at the facts by reasoning out what they ought to be; hence we may say that electrical science is ideal. In other branches of applied science, as for example in civil engineering, the corrections, factors of safety and other allowances are often much greater than the original quantity itself. In such cases it is obviously impossible to go very far from an experimental fact, by any process of reasoning. The errors would immediately become so magnified that the truth would be greatly distorted or lost entirely.

To take a concrete example, the losses in transforming electrical energy are only two or three per cent., and if an error of ten per cent. is made in calculating these losses, the actual error is only two- or three-tenths of one per cent. It would, therefore, be possible to design a system in which electrical energy was transformed many times, and yet the final error would only be one or two per cent. If, on the other hand, the losses in mechanical engineering are ten or twenty per cent., or even fifty per cent., as is often the case, an error of ten per cent. in calculating these quantities would soon become multiplied to a large figure.

Exactness in electrical units and terms is another strong point of electrical engineering, because definiteness in terms and ideas go hand in hand. The system of electrical units is complete and scientific, being based directly upon the C. G. S. system, and is the only example of a set of units which are universally adopted. The metric system is not in use in the United States, England and her possessions and many other countries, but the same electrical units are accepted by all nations. This avoids the great confusion which arises from the use of several different units for the same thing, as is the case in steam engineering, in which at least four different heat units are commonly employed.

In electrical engineering the distinction between the various quantities are usually more clearly understood, as for example the difference between force, work and power. In other branches these quantities were often confused, and the fact that mistakes of this kind are not more often made at present, is largely due to the influence of electrical engineering in the accurate use of terms. The useful word torque has been introduced through electrical engineering although it is a purely mechanical quantity. The adoption of such terms as impedance and reactance gives a nicety of expression which is rarely found in other applied sciences.

The facility and accuracy of electrical measurements contributes greatly to the precision of electrical engineering. Volts and amperes can be easily, quickly and accurately measured by means of convenient portable instruments. The product of these volts and amperes gives the watts or power which is the most important quantity.

If desired, a single instrument—the wattmeter—can be used to combine the two quantities. Electrical resistance can also be measured easily and quickly, and with still greater accuracy. Even the less common electrical quantities, such as capacity and inductance, can be measured without much difficulty and with reasonable exactness. The magnetic quantities are also quite easily and correctly determined. As already stated, the most doubtful factors in electrical engineering are the mechanical ones.

The enormous range in electrical engineering is still another proof of its precision. The same laws and principles which apply to the almost infinitesimal galvanometer current are equally applicable to the current from an electric light station. The former may be only a hundred billionth of an ampere and the latter reaches ten thousand amperes, which is a thousand million million (10^{15}) times greater.

An even greater ratio than this represents the range of resistance measurements. In the case of large copper bars, a determintaion to within .000001 ohm is often required, and for insulation testing 10,000 megohms is not an unusually high figure. This gives a range of measurement of ten thousand million million (10^{16}).

An electrical instrument, the bolometer of Professor Langley, is used to measure the heat received from the fixed stars, and electricity is also the agent selected when 100,000 horse-power are to be distributed from Niagara. Instead of saying that elec-

tricity is selected for these extreme uses, it would be more correct to state that it must be employed, just as it is the only means of transmitting speech a thousand miles, or performing the many other miracles of which it alone is capable.

The directness and high efficiency with which electrical energy can be converted into other forms is another fact which gives exactness to our work. It can be transformed into heat, light, magnetic, mechanical or chemical energy, by the simplest means, and conversely, the latter forms, with the possible exception of light, can be readily changed into electrical energy. In most cases the conversion is almost perfect, the efficiency of an electric motor or dynamo being usually over 90 per cent. and often 93 or 94 per cent. The chemical energy in a storage battery represents nearly 90 per cent. of the watt-hours applied to it, assuming the losses in charging and discharging to be about equal. The storage of magnetic energy may be effected at an even higher efficiency of 97 or 98 per cent. and the conversion of electrical energy into heat is complete, the efficiency of an electric stove actually reaching the ideal figure of 100 per cent. The production of light cannot be accomplished so economically, nevertheless the arc lamp has a far higher efficiency than any other source of artificial light, although it is usually stated to be only 8 or 10 per cent. It is also more than probable that the long-sought-for high efficiency lamp will be an electric one when it is finally invented. This facility and economy of transformation puts electricity directly in touch with the other sciences and their applications, avoiding the chances for error which round-about processes necessarily involve. None of the other forms of energy possesses anything like the same convertibility. The one serious difficulty in connection with electricity is the fact that its generation requires a boiler, engine and dynamo, bringing in heat and mechanical power as steps in the process. If this complication could be avoided, and electrical energy produced directly from the chemical energy of the coal, the only limitation would be removed. This has already been done in an experimental way, and by the substitution of water-power for steam, one piece of apparatus and one form of energy are eliminated, but the complete independence of electrical engineering and the realization of all of its possibilities will be secured when the direct conversion of fuel energy into electrical energy is accomplished practically.

It has been shown that there are no less than eight substantial

grounds upon which the precision of electrical engineering is based. The consideration of these has incidentally brought out several concrete examples, but it will be well to cite a few other special instances which demonstrate electrical exactness.

The one which first claims our attention not only on account of its historical precedence, but also from its wonder-compelling results, is the locating of faults in ocean cables. In this connection I quote from information kindly furnished me by one of the vice-presidents of the INSTITUTE, Mr. A. E. Kennelly, who has had a long and successful experience in this branch of the profession. He states that "In the case of cable coiled in a tank and which has been taken into the tank over a measuring drum without being subjected to any considerable tension, the precision with which a fault in the gutta percha can be located is sometimes very considerable. I have known one or two cases in which a fault has occured in a length of say thirty miles of cable immersed in water and maintained at practically one temperature in the tank, and in which, by means of the Varley loop test repeated many times and under various conditions to eliminate constant errors, the electrical position of the fault has been determined to within a probable error, representing about twenty feet of length. On turning the cable over from one tank to another by a seven foot drum on which the cable makes three turns, and cutting the cable when the computed distance has been run over, the fault has been found on the drum, that is, in the sixty feet or so of cable then lying on the drum."

"As regards the location of faults in submarine cables on the ocean bed, the precision depends upon a variety of circumstances, and in general is necessarily much lower than in the case of a cable coiled in a tank. The average error in practice, or the difference between the true electrical and computed positions, is perhaps about fifteen ohms, or about one mile and a half of cable having the common resistance of ten ohms per mile. Under favorable circumstances a complete break in a cable developing a fair extent of surface exposure to the sea water at the end of the copper conductor, the electrical position can be determined within five ohms in a total conductor resistance of 1,000 ohms. In the case of a fault in the insulator, sufficiently serious to interfere with signalling, specially favorable cases will occur in which the electrical position of the fault can be determined to within one ohm when a loop test is obtainable and when the total conductor

resistance of the loop does not exceed 3,000 ohms." "I have known a case of total loss of continuity in the conductor, accompanied by perfect insulation. It occurred in lifting a cable for repairs and was within half a mile of the ship. A measurement of electrostatic capacity enabled the distance to be determined within a few yards." Other cases are given by Mr. Kennelly, and many may be found in various works and journals, but these are sufficient to show the astonishing results that are possible, as well as those that are obtained in regular practice.

The methods employed in locating faults in underground conductors are quite similar to those used for submarine cables, but the results are less striking and important. Mr. William Maver, Jr., who is an authority on this subject, cites a case in which the calculated position of a fault was 2,343 feet from the testing end of an underground cable 4,200 feet long. The defect was found at the exact point indicated. The alternative would have been the tearing up of the street and cutting through a heavy iron pipe until the fault was found, as the conduit was not provided with manholes. One way to locate a ground connection, which illustrates the simplicity and certainty of electrical testing, consists in sending a current through the conductor to the ground through the fault in the insulation. A compass carried along over the cable will indicate by its deflection or non-deflection when the fault is reached. The facility of overcoming distances and obstacles impassable to other agencies is characteristic of electricity and magnetism.

The writer has had occasion to test the resistance and position of faults ("grounds") on a very large system of underground conductors for electric lighting. Although the problem was complicated by the fact that it was a three-wire system which extended several miles, it was found possible to determine the insulation resistance of each of the three conductors. The position of a "ground" is shown by the potential difference between the conductor and the earth, being a minimum at that point. For example, if a ground connection exists on the positive wire and a considerable current flows through it into the earth, the potential of the earth at that point will be raised above its normal value. The potential difference existing between the wire and the earth is actually less near the ground connection. This may be measured from the station by using the "pressure wires" ordinarily laid with the feeders, and special wires which connect to the ground at various points of the system.

The paper on "The Alternating Current Induction Motor," presented by Vice-President Charles P. Steinmetz at this meeting of the INSTITUTE, affords an excellent example of the marvelous precision of electrical engineering. In Figs. 1 and 2, two curves are shown which give the efficiency, speed, power-factor and other characteristics of a three-phase induction motor under various conditions. These curves were all predetermined by calculation. In the same figures the results obtained by actual test are also marked by small crosses. The agreement in all cases is so close that curves plotted from the actual results of tests would practically coincide with those predicted by calculation. This is all the more remarkable when it is remembered that the three-phase motor is one of the newest of electrical machines, and is a difficult problem from a theoretical standpoint. It has long been possible in designing direct current machinery to predetermine the results with almost as great accuracy as that shown in the curves of Mr. Steinmetz, but of course that is a much older problem. Nevertheless, the predetermination of results in direct current machinery is fully as difficult as in the case of alternating current apparatus, because permeability is the most doubtful factor in such calculations and is especially so at the high flux densities used in the former. It is to be observed, however, that any error in the permeability data can be corrected by increasing or decreasing the ampere-turns on the field magnet. This is easily accomplished by providing five or ten per cent. greater M. M. F. than the calculations require, which may be reduced, if necessary, by the introduction of resistance. Since the energy used for the field is a very small percentage of the total amount, it may be considerably varied without materially affecting the other factors in the machine. Sparking at the commutator brushes is an additional and by no means simple question which confronts the designer of direct current apparatus. I remember, however, being informed by Mr. Gano S. Dunn several years ago that he had found by experience in many cases that the efficiency of a direct current dynamo or motor can be predetermined from the drawings before the machine is built, within a fraction of one per cent.; in fact, he relied more upon his calculations than upon an actual test of the completed machine, even when performed by skilled men. In one case the calculated efficiency was 93 per cent. and the result obtained by test was 92.7 per cent., and in another case the total flux was found to be 1.38

per cent. greater than the computed value. This agreement is somewhat closer than is found in every day practice, but is not accidental and can usually be approximated by careful work.

We naturally suppose ourselves to be familiar with mechanical energy and heat; but as soon as we convert these well known forms of energy into that extremely subtle and mysterious agent —electricity—it immediately becomes far more definite and convenient to control, measure, transmit and utilize. In becoming intangible, it forthwith acts as the most reliable and matter-of-fact tool in the hands of those familiar with it. For example, the quickest, neatest and most exact method of making a test of mechanical friction, or the power required in any given case is by the use of an electric motor. In this way, for example, we can determine the friction of different bearings or lubricating oils under various conditions of pressure and speed, or the power consumed by fans, pumps and other machines.

Quite a striking example of the possibilities of electrical measurement is the determination of the E. M. F. of a dynamo machine without running it, which I saw successfully carried out more than ten years ago. All that is necessary is to measure the torque exerted by the machine with a given current in its armature. This may be accomplished by simply clamping a stick of wood to the pulley and weighing the pull at a given radius by means of a spring balance. It the same machine were run as a dynamo and had no losses, it follows that

$$\frac{EI}{746} = \frac{2\pi r S P}{33{,}000},$$

whence

$$E = \frac{r S P}{7.04 I},$$

in which r is the radius at which the pull is measured, S is the speed in revolutions per minute at which the dynamo is to be run, P is the pull in pounds at the given radius and C is the current in amperes. The field strength is supposed to remain the same. This method is correct whatever the efficiency of the machine may be. The electrical and magnetic losses due to the $C^2 R$ effect in armature, field current, eddy currents and hysteresis do not enter this problem. Even the mechanical losses arising from friction of bearings, brushes, etc., may be eliminated by measuring the pull plus the friction and then minus the friction, the actual pull being one-half the sum of these two results. The

effect of friction may also be gotten rid of by tapping the shaft when the measurement is made. It certainly strikes one as strange that E. M. F., which depends upon cutting lines of force, can be determined while the machine is standing still.

In electro-chemistry and electro-metallurgy quantitative relations are particularly precise. The ampere being defined as the current which deposits .001118 grammes of silver per second, the weight of any other substance is by Faraday's laws proportional simply to its chemical equivalent. This definition eliminates any error in passing from the electrical to the chemical data, or vice versa. The volt is also defined electro-chemically in terms of the E. M. F. of a Clark cell.

The author presented before the INSTITUTE, in May, 1888, a paper on "The Possibilities and Limitations of Chemical Generators of Electricity,"[1] in which the weights of materials, E. M. F. and other data were given for various voltaic combinations. Some of the figures were obtained by experiment and some by calculation. The paper also gives the E. M. F. produced by combinations of thirteen of the most important metals with chlorine, bromine and iodine, respectively. The average difference between the calculated and tested values was less than one-tenth of a volt. Even this small error is practically eliminated when the results are corrected by the equation of Helmholtz, that is, by adding the quantity $\pm T\frac{dE}{dT}$, in which T is the absolute temperature and E is the E. M. F. of the cell. Since the weights of materials liberated or consumed by a given current in a given time can be definitely predetermined and the voltage due to a certain chemical combination can also be accurately calculated, almost any problem in electro-chemistry or electro-metallurgy is susceptible of being quite easily and correctly solved.

That branch of electro-chemistry and metallurgy which employs electrical heating methods is also very definite, the exact amount of heat in gramme-degrees produced by an electric current being always given by the simple expression, $.24\ I^2\ R$, or $.24\ E\ I$.

In support of the proposition advanced in the title of this address, I am able to produce most interesting personal testimony. Mr. Edison and Mr. Tesla have independently expressed to me their opinion that electrical knowledge had become so definite and general that almost anyone could apply it, and comparatively

1. TRANSACTIONS, vol. v., p. 227.

little opportunity was left for invention. They believed that chemistry and thermodynamics were far more uncertain and therefore offered a much better field for improvement. These views were expressed several years ago, and subsequent events have shown that they contain a great deal of truth. It is a fact that electrical engineering has advanced along the lines laid down by these and other great inventors, and it is also true that much of the work has been done by the rank and file of the profession. The trails blazed by the pioneers have since become broad highways with many branching roads, built for the most part by common workmen. On the other hand, the discovery of the Röntgen ray has since been made; and both of these investigators have given much valuable time to it. It would seem, therefore, that the electrical principles and laws of to-day are true for all time, and afford a firm foundation for unlimited future progress, but that there are also many additional facts yet to be discovered that are well worthy of the efforts of the greatest genius.

In conclusion, the following quotation from the preface of Maxwell's great work on Electricity and Magnetism is appropriate. "The important applications of electro-magnetism to telegraphy have also reacted on pure science by giving a commercial value to accurate electrical measurements, and by affording to electricians the use of apparatus on a scale which greatly transcends that of an ordinary laboratory. The consequences of this demand for electrical knowledge and of these experimental opportunities for acquiring it, have been already very great, both in stimulating the energies of advanced electricians and in diffusing among practical men a degree of accurate knowledge which is likely to conduce to the general scientific progress of the whole engineering profession."

These words were written in 1873, and yet they show strong confidence in the accuracy of electrical methods and full appreciation of the close relationship between electrical science and engineering, as well as their beneficial effects upon each other. At that time the telegraph was the only practical application of electricity. What language would express Maxwell's wonder if he were alive to-day!

A paper presented at the 14th General Meeting of the American Institute of Electrical Engineers, Eliot, Me., July 28th, 1897.

THE ENCLOSED ARC LAMP.

BY W. H. FREEDMAN, H. S. BURROUGHS AND J. RAPAPORT.

Statistics show that the enclosed arc lamp is not only rapidly increasing in the point of numbers installed, but actually replacing, in many instances, the open arc lamp. The fact that one set of carbons will last from 75 to 150 hours, according to the make of the lamp, is in itself sufficient to explain the successful and rapid introduction of this form of lamp. Feeling, however, that there were many facts and much data that could be presented in relation to the enclosed arc lamp, a large number of tests were carried on, the main results obtained being presented in the following paper.

Obtaining samples of the Manhattan, Helios, Bergmann, Imperial, Pioneer, Thomson 75-hour and Thomson 100-hour lamps, tests were made bearing upon the relation between length of arc and voltage across the arc, the regulation, life of carbons, ratio of consumption of positive and negative carbons, and the distribution of light.

The method was adopted of assigning a number to each make of lamp, and using that, instead of the name of the lamp, in stating the results.

Mechanism of the Enclosed Arc Lamp.

All of the enclosed lamps now on the market, work on the same general principles. They are placed singly across the ordinary incandescent lighting circuit, and are regulated to take, approximately, 80 volts across the arc, the rest of the potential being consumed in the regulating solenoid and extra resistance (shown in Fig. 1). There is a marked difference between all of these and the ordinary open arc. The standard current is five

amperes, the arc being about $\frac{5}{16}''$ long, while the carbons burn nearly flat instead of taking the shape as in the case of the open arc. This makes a change in the distribution of the light, com-

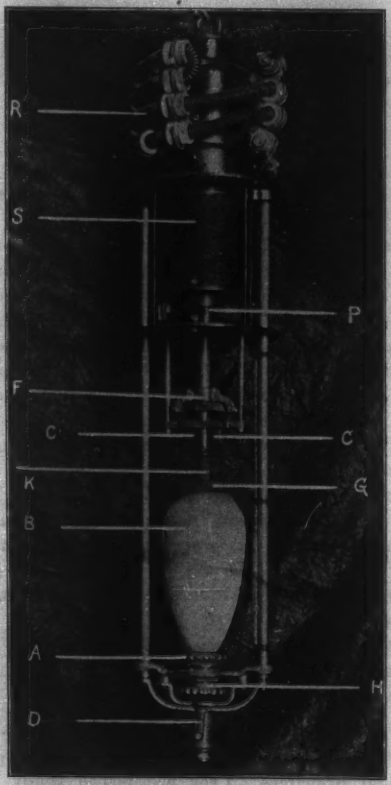

FIG. 1.—Carbon Feed Lamp. Lamp is about 30″ long, whereas lamps with Carbon Rods come as long as 40″.

R Extra Resistance.
S Solenoid.
P Plunger with Dash-pot attachment.
F Friction Clutch.
CC Contact pieces of Clutch.
K + Carbon.
G Gas Cap.
B Inner Globe.
A Inner Globe Holder.
H — Carbon Holder.
D Holder for Outer Globe.

pared with the open arc, which will be shown by curves later on. Fig. 2 shows the difference in appearance of the carbon in the two styles of arc. The enclosed arc burns flat on the top or positive carbon, the lower or negative one becoming slightly convex. The arc itself does not remain in any one spot, but wanders all around the flat ends. In the case of large carbons, this is objectionable, as it causes rather heavy shadows to be cast, which to a large extent, can be prevented by the use of proper globes. The experiment was tried of rounding the ends slightly. This arrangement did away with the shadows, but the carbons burned flat again in a very short time.

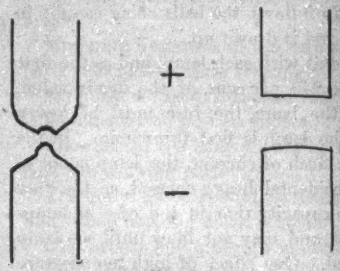

FIG. 2.

FIG. 3.

The current passes through the extra resistance, the solenoid and the carbons, in series. This series arrangment makes a very simple lamp, with very few parts, and working much steadier than the open arc lamp. When no current is passing, the carbons touch; the moment the current is thrown on, the core is drawn up, carrying the positive carbon by a friction clutch. The negative carbon is fixed in a holder or socket, at the bottom of the lamp.

The simplest form of friction clutch consists of a straight horizontal rod fastened to the end of the plunger of the solenoid,

and having at each end an arm so pivoted that these two arms cross each other like a letter X (as shown in Fig. 3). At each lower end of these arms is pivoted a friction piece, with either a rounded or a V-shaped surface, that grasps the rod holding the upper carbon. Lifting the upper ends causes the lower ends to come nearer together, thus gripping the rod. The carbon and its rod are dropped when the device falls far enough to touch a stop that prevents the lower part of the clutch from coming down any further. A novel departure from this form of clutch consists of a cylindrical piece of brass, fitting around the rod, and having its upper end grooved to hold a row of steel balls. These are held in place by a conically-shaped cup. When the inner cylinder rests on the stop, the cup, which is attached to the plunger, descends far enough, by reason of its sloping sides, to release the friction on the balls and the carbon rod falls. When the core is drawn up, the cup follows, the balls being caught in the apex of the cup, and the rod is drawn up.

Fuses should be put in circuit with each lamp, and as the first rush of current is from 40 to 240 per cent. of the steady value, according to the make of the lamp, the fuse must be heavy enough not to blow when the lamp is first thrown in. In the case of lamps having a large flush of current, the lamp is not so well protected against an accidental heavy current, as the fuse must be of greater carrying capacity than in the case of lamps with a small flush of current, and may not blow until the lamp has been seriously overheated. One effect of high temperature around the working parts, is to make the brass rod that carries the upper carbon, stick, the surface losing its smoothness, so that in some cases it is necessary to take the rod out and polish it. The current is usually carried to the upper carbon by means of two brushes pressing on this rod. As the carbons wear away, the armature of the solenoid gradually descends, the current remaining practically constant whatever the position of the plunger, until it reaches the stop that releases the carbon from the friction clutch; the carbon then falls and strikes the lower one, but is immediately picked up again,—the light sometimes going out and sometimes remaining. This process, however, occurs at comparatively long intervals as the core has a play of $\frac{1}{8}''$ to $\frac{1}{4}''$ before the stop is reached. The positive carbon wears away at the rate of .05 of an inch, approximately, per hour, and the negative at half this rate; there will consequently be from 5 to

8 hours between the times of the resetting of the core to its top position. The open arc lamp, allowing a consumption of one inch per hour, feeds about 15 to 20 times as much.

A good lamp should have the following points, the determination of which was one of the objects of our experimental work:

Long life for one set of carbons;

Simple and light, but strong mechanism;

Lamp must be short, for use in low-ceiling rooms;

Must cast no shadows from the carbon points, and it must not be necessary to use very dense globes to obtain this result;

Smallest possible amount of deposit on the inner globe;

Smallest possible flush of current at start;

Lamp should pick up immediately when the carbons have fallen together;

Carbons should drop immediately at feed and if the arc should break;

Minimum hysteresis in the core and no friction of the moving parts sufficient to cause sticking;

Lamp should be so insulated that when the current is on, there is no uninsulated portion exposed;

The shell of the lamp should be readily removable so as to expose the working parts;

The outer globe should be easily removable and so fastened that, when hanging down it cannot be dropped or broken;

Old carbons and inner globe must be easily removable;

Both globes must admit of easy cleaning;

It should be easy to replace and centre the carbons;

The lower carbon holder and inner globe holder must be held firmly in place, and the arrangement for making the small bulb air-tight at the bottom should have no tendency to crack the glass or get it out of centre;

Regulating mechanism should give the smallest possible flickering of the light;

The dash-pot should be firm enough to resist sudden changes, but must not be so much so that it is slow in getting to its normal position.

Length of Arc.

In order to measure the length of the arc for different values of the voltage across it, the image was projected on a screen, on which the diameter of the carbon and the length of the arc were measured. The former being known, the true value of the

length of the arc was determined by simple proportion. The results are given in Table I, and shown graphically in Fig. 4.

TABLE I.

VOLTAGE ACROSS ARC.	LENGTH OF ARC.
83	0.326″
82	0.316″
76.5	0.271″
71	0.217″
67.5	0.184″
62	0.130″
60	0.125″
35	0.011″

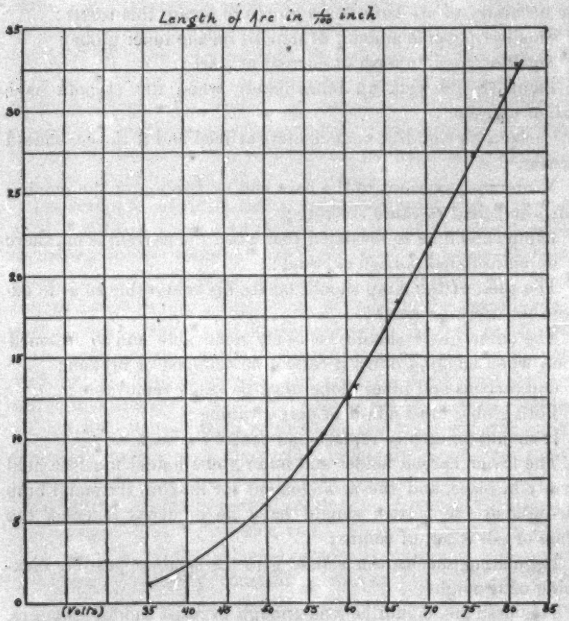

FIG. 4.

REGULATION.

The simple regulating mechanism of the enclosed lamp has a very great advantage over that of the ordinary open lamp. The series mechanism is not applicable to short arc lamps, as a given variation makes a large proportional change, whereas this is obviated by using a long arc. The current and voltage variation in

both styles of lamp at starting, each on a constant potential circuit of 115 volts and the open arc being one of two in series, are shown in Table II and Fig. 5.

TABLE II.

TIME.	Enclosed Arc.		Open Arc.	
	Voltage.	Current.	Voltage.	Current.
0	74.	8.1	89.	18.
1 second	74.5	5.2	—	—
15 "	74.5	5.0	33.	19.4
30 "	75.	5.1	30.	21.
45 "	77.	4.8	—	—
1. minute	75.5	5.3	25.	22.
1.5 "	76.	5.1	35.	18.6
2. "	78.	4.8	38.	18.
2.5 "	78.	5.0	—	—
3. "	81.	4.6	40.5	17.1
3.5 "	80.	4.6	—	—
4. "	80.	4.7	43.	16.1
4.5 "	77.5	5.0	38.	20.6
5.5 "	77.	5.2	—	—
6.0 "	79.	4.8	42.	19.0
6.5 "	79.	4.9	—	—
7. "	77.5	4.9	41.	16.4
7.5 "	80.	4.7	42.	16.
8. "	79.	4.9	41.	16.4
8.5 "	81.5	4.6	—	—
9. "	83.	4.3	43.	14.9
9.5 "	79.5	4.8	42.	15.5
10. "	76.5	5.1	44.5	14.
10.5 "	76.	5.2	—	—
11. "	78.	5.0	41.5	14.6
11.5 "	81.	4.7	44.	8.
12. "	80.	4.5	42.5	8.
12.5 "	79.	4.6	—	—
13. "	81.5	4.3	42.8	8.9
13.5 "	76.	4.9	45.	7.
14. "	79.	4.6	45.5	7.2
14.5 "	80.	4.3	38.5	11.
15. "	79.5	5.1	36.	9.8

The voltage is that across the arc. The normal currents were 4.75 for the enclosed and 8 for the open arc lamp.

The normal voltage across the arc, for 5 amperes, in the enclosed lamp is 80. This gives 400 watts expended at the arc, the rest, depending upon the voltage of the circuit, being wasted in the extra resistance. On a 110-volt circuit, this would give $72\frac{7}{10}$ per cent. of the energy supplied to the lamp spent at the carbon points. Eighty to 85 volts seems to be as high as is desirable to get the best regulation. Some extra resistance is necessary for regulation, as a given change in the resistance of the arc will make a less change relatively in the whole resistance when this is large.

It might appear advisable to run a special circuit of lower voltage to feed these lamps if they are of sufficient number. To determine how low the voltage may be carried on a regular commercial lamp such as is supplied for the standard voltage, the

external resistance was gradually cut out until the regulation of the current began to get poor. The lamp tested had an extra resistance of 6 ohms. The solenoid was very nearly one ohm.

On the external resistance being cut down to 3.1 ohms, the current became 4.8 amperes, while the voltage across the arc was 78 and across the lamp 100. No appreciable change was noticed in the steadiness of the lamp. This arrangement consumes 480 watts, total, and 374 across the arc, which latter remains practically the same. On a 115-volt circuit, where the lamp is normally run, the watts per lamp are 552, making a saving for this partic-

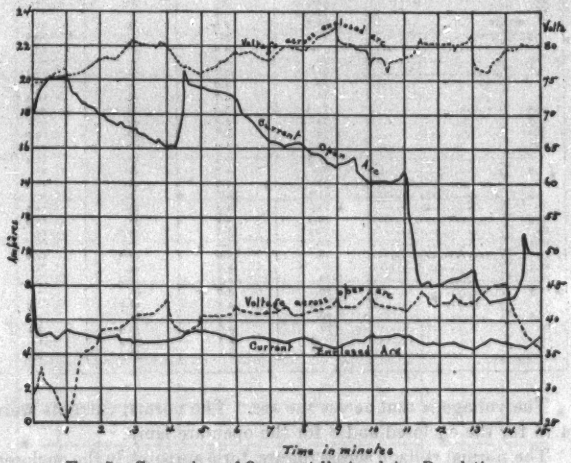

FIG. 5.—Comparison of Open and Enclosed Arc Regulation.

ular case of 72 watts. For every 100 lamps on the 115-volt circuit, 113 could, therefore, be run on the 100-volt circuit for the same number of watts consumed.

The external resistance was next reduced to 2.3 ohms when the current became 4.85 amperes, the voltage across the lamp 95, while across the arc it remained at 78. As the extra resistance is cut out, the value of the current is slightly increased. At this voltage the current was too unsteady and caused considerable flickering. For out-door use this would not be noticeable, but for indoor use, such as reading and the like, it would be very objectionable. All the lamps tested, showed flickering on a sheet

of paper held a few feet away from the lamp. This experiment of lowering the voltage was performed with a small Edison machine, varying the field resistance to give the desired voltage.

Table III will be of interest in showing the steadiness it is possible to get, in current and voltage across the arc. The readings were made every two seconds on lamp No. 7. The results are also plotted in Fig. 6. Considering that the arc is constantly moving, and that the external voltage is not absolutely steady, the regulation is very good.

The largest swing noticed was from 5 to 5.3 amperes. Some of the lamps vary considerably in voltage at the start, taking

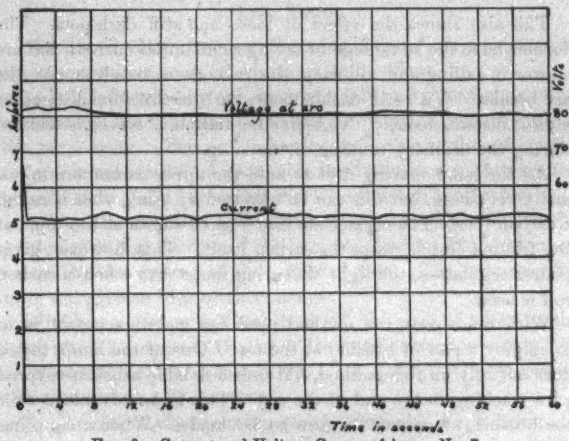

FIG. 6.—Current and Voltage Curves of Lamp No. 7.

TABLE III.

VOLTAGE.	CURRENT.	VOLTAGE.	CURRENT.
82	6.75	80.5	5.2
82.5	5.2	80.5	5.1
82	5.1	80.5	5.2
83	5.1	80	5.2
81.5	5.2	80.7	5.1
81	5.3	81	5.2
80.5	5.1	80.5	5.2
80.5	5.2	80.5	5.1
80.5	5.1	80.5	5.2
80.5	5.2	80.2	5.2
80.5	5.1	80	5.1
80.5	5.2	80	5.2
80.5	5.2	80.2	5.2
80.5	5.1	79.5	5.2
80	5.3	80	5.1
80.5	5.2		

about five minutes before their average voltage can be determined. The above lamp remained the same during its further run.

Table IV shows the initial rush of current compared to the average.

TABLE IV.

LAMP.	INITIAL CURRENT.	AVERAGE CURRENT.
1	8 to 9	4.75
2	9 to 9 7	5.0
3	8.5 to 9	4.9
4	12	5.0
5	7.5	4.9
6	11.3	5 15
7	6.75	5.15

This also shows the effect of loose and stiff dash-pots. The former have the advantage of taking small initial current, but are slower in falling and allowing the carbons to touch in case the arc breaks. With stiff dash-pots the carbons are forced together almost instantaneously. No better regulation, however, is secured during the ordinary running of the lamp.

All the lamps having rods to hold the upper carbon are necessarily very long, but this can be obviated by using what is called a carbon feed. The carbon fits into a small sleeve at the top, but the friction clutch grasps the carbon itself. This, however, gives poorer regulation, the light flickering more than when a carbon rod is used.

With brass rods, the method used for making contact is to to employ a pair of brushes at the top. One of the lamps tested does not rely on this method, but uses a flexible asbestos-covered wire reaching to the end of the rod. This is an advantage over the brushes, as contact is sure to be made. When a lamp has been run for some length of time, getting the mechanism thoroughly heated, the rod gets sticky from what appears to be shellac. In one case noticed, the rod was so discolored and dirty, after about 200 hours use, that the current would not pass from the brushes to the rod, the carbons being together. This shows the necessity of cleaning the rod at the end of every run. The rod must be easily and quickly detachable, or else so arranged that it can be cleaned throughout its whole length.

To get an idea of the variations in current of the different lamps, the ammeter in circuit was watched, and the data obtained is given in Table V. No lamp remains absolutely steady for more than a few seconds at a time.

TABLE V.

LAMP.	REGULAR VARIATIONS.	OCCASIONAL VARIATIONS.
1	4.5 to 5.0	4.5 to 5.3
2	4.5 to 5.5	
3	4.7 to 5.1	4.3 to 5.4
4	4.7 to 5.2	4.5 to 5.4
5	4.7 to 5.1	4.6 to 5.2
6	4.9 to 5.5	Flickers considerably.
7	5.0 to 5.25	5.0 to 5.4

The best regulation was obtained from lamps Nos. 3 and 7. Although the arc has more chance to move about on the $\frac{1}{2}''$ carbons than on the $\frac{1}{16}''$, lamp No. 3, using the latter, gave no better regulation than the one with the $\frac{1}{2}''$ carbons.

Life Tests.

The life of a lamp for one trimming, depends on a large number of conditions, most of which are self-evident.

1. It is influenced by the size and quality of the carbons. The carbons will not run exactly the proper diameter, even though of the same make. This, while hardly noticeable to the eye, is discovered when it is found impossible to slip the carbon through the gas cap or in the lower socket and hole through the bottom.

2. The life depends upon the current strength. This varies gradually during the run of the lamp, on account of the plunger, caused by the wasting of the upper carbon. The following figures will give an idea of this change:

With upper carbon full length of 12″, the current taken by the lamp was 5.2 amperes. Carbon 9″ long, the current was only 5.05 amperes; while, when carbon was only 6″ long, its final length, the current was 4.85 amperes.

3. The size of the enclosing globe affects the life, it being less by a slight amount for a smaller globe. All the other conditions being the same, a lamp having a smaller globe will, during a given run, have its globe replenished with air from the outside oftener than if it had a larger globe.

Table VI gives the carbon consumption in inches per hour for 5″ and 6″ globes.

TABLE VI.

CONSUMPTION.	5″ GLOBE.	6″ GLOBE.
Positive	.067	.0687
Negative	.034	.029
Total	.101	.0977

4. The rate of consumption of carbon varies with the height of the arc in the globe. Although the current decreases in value

as the upper carbon is consumed, the total consumption per hour is increased as the position of the arc goes downward in the globe. The measurements given below, in Table VII, show this, which is a result of the increased circulation caused by the heat of the arc being lower in the bulb.

TABLE VII.

POSITION OF ARC IN BULB.	CONSUMPTION PER HOUR. Positive.	Negative.	Total.
Top	.070	.024	.094
Middle	.074	.034	.108
Bottom	.079	.039	.118

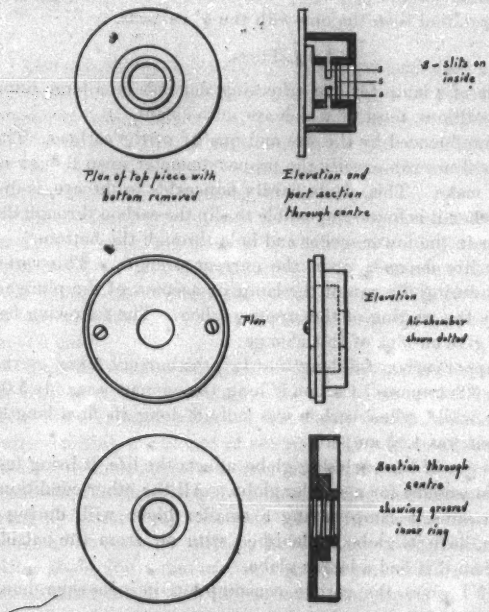
3 – slits on inside
Plan of top piece with bottom removed
Elevation and part section through centre
Plan
Elevation
Air-chamber shown dotted
Section through centre showing ground inner ring

FIG. 7.—Gas Caps. Half actual size.

At the middle of the bulb the consumption per hour is 14% greater than at the top; at the bottom it is 25% greater. These figures are for $\frac{7}{16}''$ carbons, and are the largest for any of the lamps tested.

5. The form of gas plug used also influences the life. They

vary in form from a simple circular plate with the hole for the carbon grooved in two circles parallel with the plane of the disk, to the arrangement having a chamber fitted with slits through that wall which is next the carbon. The object of this chamber is to obstruct the circulation as much as possible, and yet have sufficient air to keep the carbon from depositing on the globe in excessive quantities. For some reason the consumption of negative and positive in one of the lamps having this latter form of cap is in the proportion of from 1 : 5 to 1 : 10. In all the other lamps the ratio of consumption of positive and negative carbons varied from 1.7 : 1 to 2.9 : 1. Since a slow consumption of the negative carbon keeps the arc well up in the globe, it gives an advantage over the other lamps in producing a larger area of distribution of light at the end of the run. On a horizontal plane it will give a little less, as the coating is heavier at the top of the globe. This holds, however, for a continuous run only; the ratio of consumption being 1:3 for intermittent runs. This shows how the effect of the gas cap is neutralized by allowing fresh air to enter at intervals.

Fig. 7 shows the different styles of caps.

6. Whether the run is continuous or intermittent will make a difference in the life, although only slight. Theoretically, the life should be less for the intermittent test than when the lamp is kept burning without any stops. The stoppage allows fresh air to get in, thus increasing the consumption. When the current is thrown off a lamp, it is to be noticed that the co gas catches fire from the inrush of air and forces its way out against the incoming currents, so that in some instances the force is sufficient to make the cap chatter in its place. The blue flame produced disappears in a time varying up to ten seconds. The results we obtained were irregular, but show that the life is about the same whether the lamp is burning steadily or at intervals, as shown by Table VIII.

TABLE VIII.

TEST.	STEADY RUN. Life in Hours.	INTERMITTENT RUN. Life in hours.	No. of Stops.
a	124	128	21
b	180	148	15
c	28	25.5	22
d		143	15
		141	20
e	128	112	18

Test *c* is not the full life. An accident compelled the stoppage of the continuous test after 28 hours, and the intermittent test was then carried on till the same amount of carbon had been consumed. It will be observed that in two cases the life was longer for the non-continuous run. Another test not given above, showed almost exactly the same loss of carbon for each run, the consumption for a given number of hours being measured.

To find, theoretically, the amount of carbon consumed with intermittent use, we can calculate the weight of oxygen the bulb contains when filled with fresh air, and from this determine the amount of carbon burned before the admission of any more fresh air. For example, one of the bulbs contained 18.8 cubic inches of air. Since the amount of oxygen contained is one fifth of

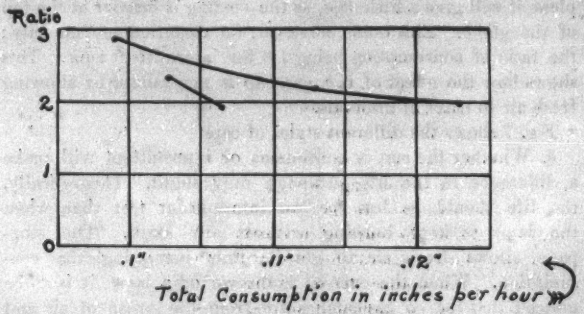

FIG. 8.

this, and a cubic inch weighs 343 grains, the bulb contains when filled with fresh air, 129 grains of oxygen. In forming co gas, this amount of oxygen would require .967 grain, or approximately one grain of carbon to combine with. Carbon, at a specific gravity of 2, weighs 505 grains per cubic inch. If the carbon is $\frac{1}{8}''$ in diameter, its section is very nearly .2 sq. in. and a piece one inch long will have a volume of about .2 cu. in. and weigh approximately 100 grains. Then, if one grain of carbon is consumed for each filling of the bulb, it means that .01″ in length has been used. Taking .07″ as an average total consumption per hour and that only .01″ is consumed by the air in the bulb at starting, it will take 7 of these renewals to consume an amount of carbon equal to one hour's regular run. That is, if the lamp

is run for a few minutes, sufficient theoretically to exhaust the oxygen in the bulb, and if this is done 7 times, it will use as much carbon as if the lamp had been running steadily for one hour. Therefore, taking 4 hours as an average run, a lamp burning 140 hours would have 35 stops, equivalent in consumption to 5 hours run, and on this basis would consume carbon as if it had burned continuously for 145 hours.

7. Some of the lamps make use of an air-tight outer globe to keep down the supply of air. This may make a slight difference in the lamp's life, but it has the disadvantage of raising the temperature inside the lamp to a very high point, making it necessary to use an insulation that will not char from the effect of the heat. It may also cause a coating of shellac that is originally put on the solenoid, to deposit on the brass rod, insulating it and causing it to stick. A thermometer placed inside the extra resistance in a lamp that was open at the top, showed 324° F. The temperature of the air around the clutch in a lamp with ventilating holes was 280° F., and that of the shell, 134° F. The inside temperature of a tightly closed lamp would probably be considerably higher.

RATIO OF CONSUMPTION OF POSITIVE AND NEGATIVE CARBONS.

For a given lamp, the ratio decreases as the total rate of consumption increases, not only for different sizes of globes but also for different parts of the same globe. This is shown by Fig. 8 and Table IX.

TABLE IX.

CONSUMPTION IN INCHES PER HOUR.			Ratio.	Remarks.
Positive.	Negative.	Total.		
.070	.024	.094	2.87	Different parts of same globe.
.074	.034	.108	2.20	
.079	.039	.118	2.02	
.0687	.029	.0977	2.37	Different globes.
.0670	.034	.101	1.97	
.0617	.00617	.0678	10.	$\frac{7}{16}''$ carbons, largest ratio observed.
.0509	.0227	.0736	2.24	$\frac{1}{2}''$ carbons.
.0467	.0216	.0673	2.16	
.0543	.0217	.076	2.50	
.046	.027	.073	1.70	
.048	.023	.071	2.08	

It will be observed that the smallest total consumption was obtained with a $\frac{7}{16}''$ carbon, showing very markedly the effect

of the gas cap. The usual method of renewing the carbons is to use the remainder of the upper carbon for the negative in the next run. In the case of the lamp just cited (No. 3) the upper carbon left is about $\frac{1}{2}''$ shorter than a new lower carbon, but since the life of this lamp is so prolonged the shortness would be no drawback. The lower carbon might even be used for two continuous runs, if the position of the arc in the lower portion of the globe is not objectionable.

The long life of the enclosed arc may be considered its chief advantage over the ordinary open arc, the saving in carbons and trimmers' expenses being very large. The old style of lamp requires two carbons for each trimming, and lasts 6 or 8 hours. The enclosed arc requires to be trimmed about $\frac{1}{15}$ or $\frac{1}{20}$ as often. Furthermore, each re-trimming costs less. For, although the cost per thousand for the same size carbon is greater for the enclosed arc, being $23 for $12'' \times \frac{7}{16}''$ rods, only one is required for re-trimming, while the open arc needs two, costing $18.70 per thousand for $12'' \times \frac{7}{16}''$ rods and $8.30 per thousand for $6'' \times \frac{7}{16}''$ rods; so that one thousand re-trimmings cost $23 for the enclosed lamp, against $27 for the open lamp, or a saving of $4 per thousand trimmings in favor of the enclosed arc lamp.

Photometric Tests.

The figures given for the candle power of the lamps when using different globes are only approximate on account of the difficulty caused by the great difference in value of the standard source of illumination and the arc, the very marked difference in the color of the light (the arc being violet around the horizontal plane and white below it, while the incandescent lamp gave an orange light even when run above its normal voltage), the wandering of the arc, and the personal error in comparing the lights. In making comparisons of the intensity of the lights we used a pencil photometer, determining the relative values of the arc and the standard lamps by means of the shadows cast by a pencil on a white card, the illumination at different angles being obtained by raising the lamp with a rope and pulley. If the carbons were not kept exactly centered, the angle of maximum intensity could be shifted all around. Our figures for the different angles were obtained by taking the mean of about ten readings, taken around the surface of a cone whose slant is the same angle as that of the given angle. These mean values were

then plotted, and from the area of the resulting curve the value of the radius of a circle of equal area is calculated. This radius gives the value of the mean hemispherical, or spherical candle-power, as the case may be.

By means of a standard candle (British, having a 45 millimetre flame) an incandescent lamp was calibrated at a constant voltage, obtained by the use of several resistance boxes in parallel and all in series with the lamp. This lamp was recalibrated at frequent intervals.

The inner globes furnished by the different manufacturers vary in density, from a globe that will show the unlit carbons inside very plainly, to a form that is so dense as to be translucent, but not transparent. This latter form diffuses the light

FIG. 9.—Shadows of Side Rod and Carbon Tip from use of Clear Inner Globe.

FIG. 10.—Opal Inner Globe, used for making Outer Globe free from Shadows.

better than a thinner globe, although cutting off more light. All the opal globes, when held up to a window, show a reddish orange color, which has the effect of softening the violet light cast by the naked arc. The use of a fairly dense opal inner globe and a light outer globe gives a soft light that is pleasing to the eye and free from shadows. Figs. 9 and 10, which are reproductions from photographs, show the shadow cast when a clear inner globe is used, and the softening effect of an opal inner globe, which makes a light entirely free from shadows, not even the side rods showing. When an opal globe is used, it appears like a solid source of light. It is this effect that does away with the shadows of the side rods. The shadow cast by the bottom of the lamp is also made very small, so that the effect to the eye

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is that of a bright, even illumination, apparently as much as the illumination from the naked arc, although the intensity has been cut down considerably by the globes. This is due to the fact that a light very intense in one spot seems to give no more illumination than a diffused light of smaller total value.

The distribution given by an open arc lamp is not the same as that from an enclosed arc lamp. The maximum in the latter is at an angle of 25 degrees below the horizontal instead of 40 degrees. The intensity, after decreasing, reaches another high value at 40 degrees, but not quite as great as at 25 degrees. We can

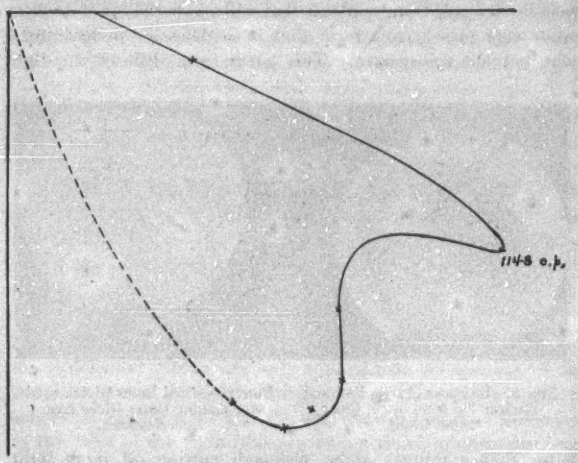


FIG. 11.

give no explanation of the peculiar form of the curve obtained with clear glass, except that it is due to the globe, as a naked arc would seem to have no cause for the uneven curve as shown. The same general variation is shown in a test on the Manhattan lamp by Houston and Kennelly (Fig. 11).

The comparative distribution of light in both forms of arc is shown by Table X. The figures given for the open arc are those of Wybauw, Palaz "Industrial Photometry," p. 236.

These are comparative, not absolute values. It will be seen that the enclosed arc gives a wide zone of illumination that is not far from the maximum.

TABLE X.

ANGLE BELOW HORIZONTAL.	ENCLOSED ARC.	OPEN ARC.
0	132	208
10	455	401
20	755	612
25	1000	
30	900	871
40	990	1000
50	888	807
60	548	457
70	465	188

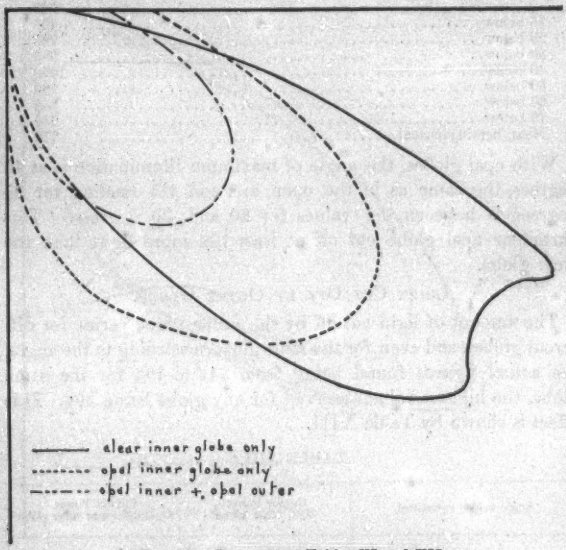


FIG. 12.—Curves from Tables XI and XII.

TABLE XI.

CLEAR INNER GLOBE.

ANGLE FROM HORIZONTAL.	CANDLE POWER.
20 above	89
10 above	82
0	139
10 below	501
20 below	980
25 below	1397
30 below	1300
40 below	1355
50 below	1060
60 below	674
70 below	414
Mean hemi-spherical	850

The actual values with a clear inner globe, obtained by us, are shown in Table XI. Replacing the clear globe with an opal one, we obtained the values given in Table XII. All of these results are shown graphically in Fig. 12.

TABLE XII.

OPAL INNER GLOBE.

ANGLE FROM HORIZONTAL.	CANDLE POWER.
20 above	152
10 above	184
0	347
10 below	455
20 below	735
30 below	985
40 below	1050
50 below	969
60 below	855
70 below	784
Mean hemi-spherical	770

With opal globes, the angle of maximum illumination is at 40 degrees, the same as in the open arc, and the reading for 25 degrees is between the values for 20 and 30 degrees. This particular opal globe cut off at least 10% more light than the clear globe.

LIGHT CUT OFF BY OUTER GLOBE.

The amount of light cut off by the outer globe varies for different globes, and even for the same globe, according to the angle, the actual figures found being from 34% to 40% for the same globe, the highest value observed for any globe being 50%. This effect is shown by Table XIII.

TABLE XIII.

Angle below horizontal.	Candle Power. Opal inner globe.	Candle Power. Opal inner and outer globe.
0	184	123
20	844	442
40	1110	568
60	327	180
Mean hemi-spherical	652	380

HOLOPHANE GLOBE.

This is a globe of clear glass, made with vertical grooves inside and horizontal grooves outside. It is from the design of Blondel, and theoretically each groove has a different outline through its section.[1] The object is to get as near a perfect diffu-

1. For a full description of the "Holophane Globe" see *Electrical World* Jan. 23, 1897, by E. L. Elliott.

sion without loss from absorption as possible. Practically, the globe is made in several zones having the same form of groove throughout a given zone, but different in the next one. The most noticeable change we observed from its use, was in the horizontal diffusion. For a given angle, the readings in different directions around the lamp were very nearly alike, whereas in the ordinary globe these readings were sometimes in as high a ratio as 1 to 3.

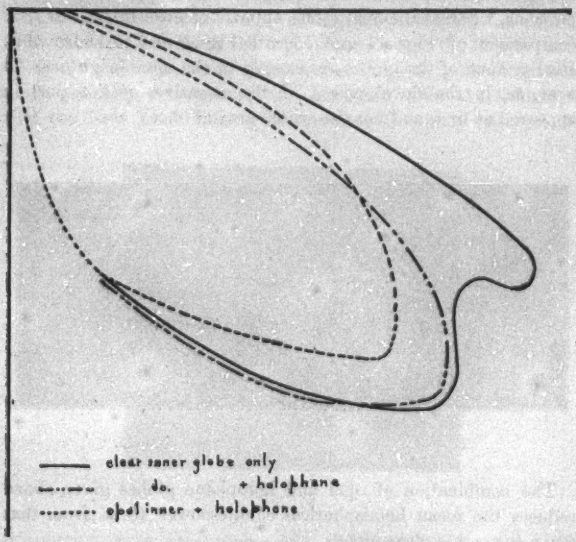


FIG. 18.—Curves for Table XIV.

TABLE XIV.

Angle below horizontal.	Candle Power. Clear inner globe.	Candle Power. Clear globe and holophane.	Candle Power. Opal globe and holophane.
0	171	96	137
10	380	335	252
20	974	496	639
25	1289	783	890
30	1273	1043	950
40	1278	1255	1116
50	1082	1051	915
60	707	852	707
70	600	689	604
Mean hemi-spherical....	854	776	700

The effect of the holophane globe on the distribution is shown by Table XIV and Fig. 13.

The holophane globe, therefore, reduces the light through a clear globe only 9.2%. This seems very small, but a test given in the *Electrical World*, Nov. 10, 1894 (Digest), gives two values, 13% and 9%.

The appearance of the globe to the eye is different from the opal globe; it has a whiter looking light, and appears darker in portions, whereas the opal globe appears of even brightness. A comparison of Figs. 14 and 15 with Figs. 9 and 10 shows this. Really, none of the globes are exactly of the same brightness all over, as, in the development of the negative, only a portion appeared at first, and not the whole area at once.

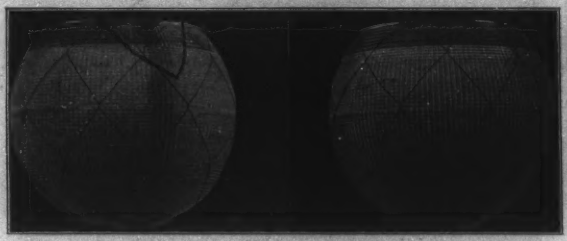


FIG. 14. FIG. 15.

The combination of opal and holophane globes given above reduces the mean hemispherical candle-power 18.1% from that given through a clear globe.

Briefly stated, we find:

For two clear glass globes, allowing 5% to 8% absorption for the outer one, the watts per candle are about 0.5, and the candles per watt 1.9;

With opal inner and clear outer, watts per candle 0.56 to 0.60, and candles per watt 1.7 to 1.5;

With both inner and outer opal, watts per candle 0.9 to 1, and candles per watt 1.1 to 1.

Also, the efficiency from the use of the holophane globe was but little less than with the ordinary clear outer globe, some of the latter not appearing to be of good quality.

Light Cut Off by Deposit on Inner Globe.

The advantage of long life, obtained by the use of larger diameter or greater length of carbon, is reduced by the fact that the deposit formed on the inner globe cuts off considerable light. In the early part of the run, this is not objectionable; but it would seem advisable not to have a run of over 130 to 140 hours. The deposits all varied in density in the same general ratio, the thickest being at the top, and the bottom being slightly heavier than the middle. The coating was analyzed, and found to contain ferric oxide at the top, carbon dust at the bottom, and silica all over. In some cases it was impossible to clean the globe properly without the use of water. (We are informed that the New York Edison Illuminating Company requires its

Fig. 16.

trimmers to carry extra globes with them, so that if any are still hot, the use of a wet cloth is not required until they can be cooled, the extra globe being substituted.)

The two globes shown in Fig. 16 show a deposit in the case of No. 1, that came from the brass cap, fused into the glass, so that water would not remove it; in the case of No. 2, it is a deposit of carbon, also fused into the glass. The carbon rod had burned to an angle of nearly 45 degrees, and the particles were projected right along this line.

The amount of light cut off by deposits on inner globe is shown by Table XV. As the arc is low down in the globe at the end of the run, the deposit at top has little effect. The middle and bottom are the important parts.

TABLE XV.

TEST.	TOP OF GLOBE.	MIDDLE.	BOTTOM.
a.....	30%	20%	20 5%
b.....	48%	18%	——
c.....	60%	14%	16%

Insulation of Lamp.

The tests made were with the tail-piece as one terminal, and the other parts of the lamp in turn as the other, the terminals of the lamp itself being included; also, between the shell and the lamp terminals. Only lamps Nos. 4, 5 and 7 were completely insulated.

Conclusion.

To sum up, we find these advantages of the enclosed arc lamp over the open:

Long life, and consequent saving of carbon, trimming expenses and annoyance from frequent renewals;

Pleasant light, free from hissing and spluttering, and with very little flickering;

Absence from flying dust and sparks, and fireproof qualities resulting from the use of two globes;

Being run on the incandescent circuit, there is no danger from high potentials, and no need of an automatic cut-out;

Simplicity of mechanism, and, consequently, less need of repairs.

A paper presented at the 14th General Meeting of the American Institute of Electrical Engineers, Eliot, Me., July 28th, 1897. President Crocker in the Chair.

ARMATURE REACTIONS IN A ROTARY CONVERTER.

BY ROBERT B. OWENS, D. W. HAWKSWORTH AND H. W. DOUBRAVA.

It was primarily desired to obtain curves showing the instantaneous distribution of induction over the pole faces of a rotary converter for different armature positions and conditions of loading.

In general the method employed to effect this, consisted in measuring the instantaneous electromotive forces under different conditions, generated in a series of small equal evenly spaced coils of fine wire wound over the armature surface. The electromotive forces in these coils in any position were of course proportional to the induction density in that part of pole opposite coil.

The machine experimented upon is of the well known consequent pole type, made by the old United States company. Its output is 3½ K. W. at 110 volts, normal speed 2,400 R. P. M.

Fig. 1, shows two views of machine. At the commutator end are seen three slip rings, connected to commutator, also the contact-maker at the end of shaft. At the pulley end are two contact rings to which the several test coils may in turn be connected. The armature is drum wound with smooth core. The commutator has 54 segments.

The machine originally designed for a continuous current generator, was changed as shown into a 3-phase converter by placing slip rings on the armature shaft and connecting segments 1, 19 and 37 of the commutator respectively to rings 1, 2 and 3. No suitable 3-phase generator being available, it was used only to convert continuous into 3-phase currents. The applied voltage at the brushes was kept exactly at 110 volts, the energy being supplied by a 15 K. W. Edison generator.

Instantaneous electromotive forces were measured by the usual zero method using telephone.

The particular contact maker used may, however, be described. An iron ring was cast in the form indicated in Fig. 2, and attached to a hard rubber disk about $\frac{1}{2}''$ thick: A A^1 are glass wedges and B is a thin steel clock spring placed between them;

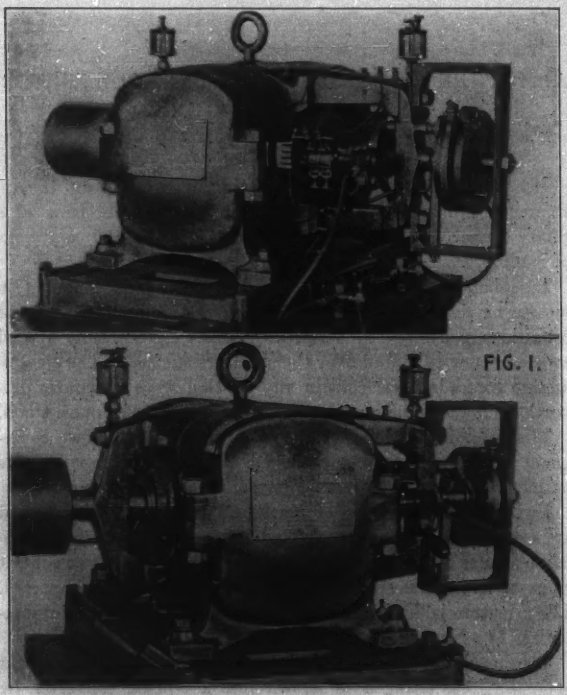


FIG. 1.

C is a screw with insulated head by which the wedges are forced into a wedge shaped slot in the rim and held firmly in place. The metallic strip B is connected to the contact ring E. The glass wedges and strip are ground even with the rim of the cast-iron ring. The contact brush which consists of two thin steel

watch springs coming in contact only with polished metal and glass surfaces wears well, and the contact is always clean and good. No difficulty whatever was experienced in reading electromotive forces to less than $\frac{1}{50}$ of a volt.

Since the object desired was to show the instantaneous in-

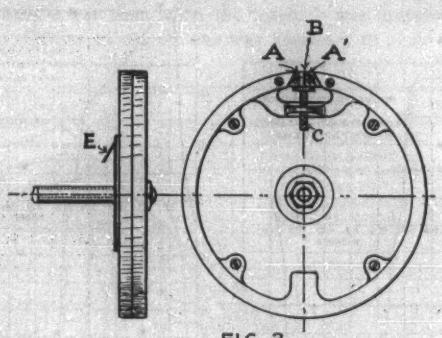


FIG. 2

duction distribution over the pole faces, and the variation in induction density at particular points on the polar surface as the armature and armature currents varied in position and value, the ordinary single or two-brush method of exploring commutator potentials for continuous current machines would evidently be useless. First a single coil of fine wire was wound lengthwise around the armature and the ends connected to the contact rings at pulley end of machine. Fig. 3 represents the

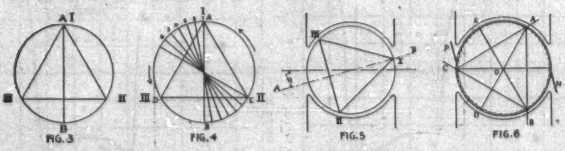


FIG. 3 FIG. 4 FIG. 5 FIG. 6

relative position of coil and three limbs of secondary circuit of converter; A B is the fine wire coil wound through the point where one contact ring is tapped; I-II, II-III and III-I represent the three limbs of the secondary circuit.

The machine was first run as a motor with no load and curve

Plate 1 obtained. This shows the induction distribution to be quite uniform over polar surface but slightly shifted in opposite direction to rotation. This would naturally be expected as the armature reactions with so small an armature current would be but slight.

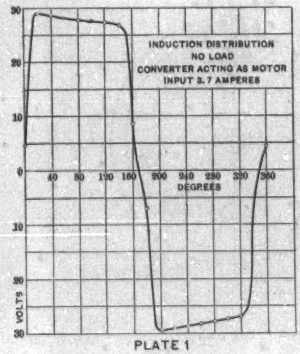


PLATE 1

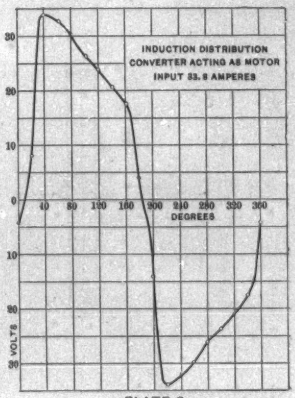


PLATE 2

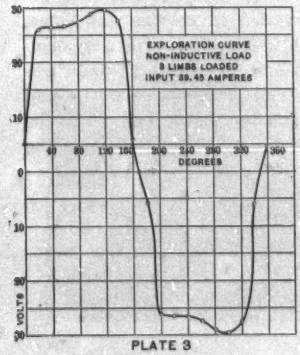


PLATE 3

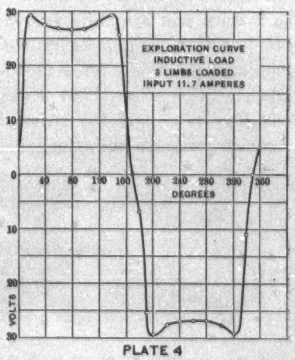


PLATE 4

The machine was again run under steady load as a motor up to about its full capacity, the armature taking 32.6 amperes. In this case the distribution curve shows a very decided distortion of the field as indicated by curve, Plate 2. Both of these curves

are exactly like what would have been obtained by the ordinary two brush method of exploring commutator.

The machine was next run as a converter, the three limbs being equally loaded with incandescent lamps. The armature took 39.45 amperes. Although in this case the armature current is much larger than when the machine was operated as a motor, no shifting of the brushes was necessary to avoid spark-

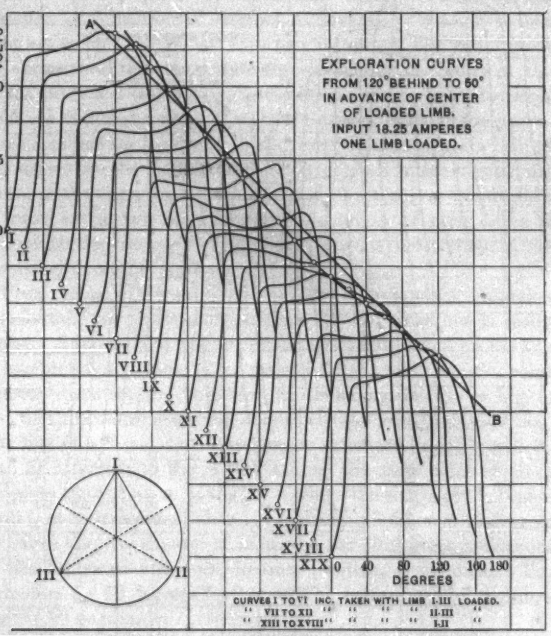


PLATE 5

ing as was before the case, showing the small reactions in a rotary converter. Curve Plate 3 is the exploration curve from the same test coil for this case, and curve Plate 4 is the exploration curve from test coil when equal inductive loads were put on the three limbs, the armature taking 11.7 amperes. The last two curves must not be confused with curves which show the in-

stantaneous distribution of induction for particular armature positions and loads. They merely show the induction at a fixed angular position from the loaded legs as the armature assumes different angular positions. From a series of such exploration curves the instantaneous induction distribution can, however,

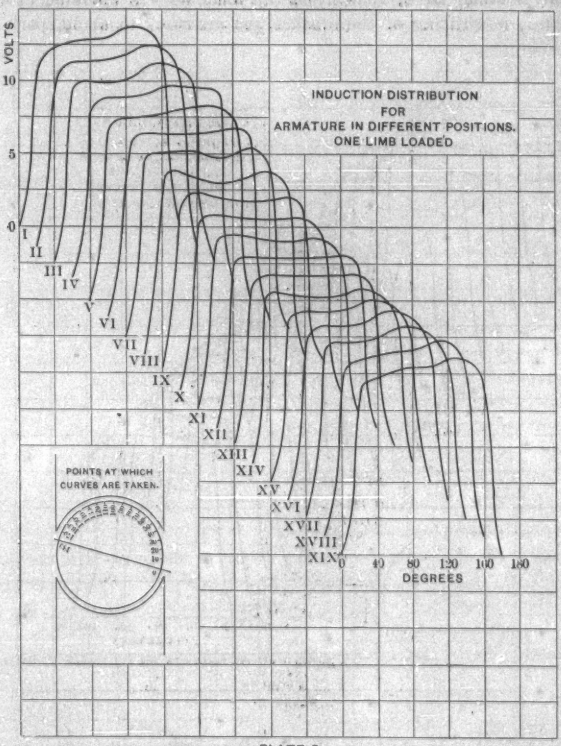


PLATE 6

be easily obtained as follows: First, we will consider the case of a single limb loaded. It will be seen by an inspection of Fig. 4 that placing test coils 10 degrees apart at points 1, 2, 3, 4, 5, and 6 and taking readings from each separate coil with limbs

I-II, II-III and III-I loaded separately, is the same as having but one limb loaded, and coils placed 10 degrees apart entirely around the armature, the three armature windings being known to be practically identical. When the limb I-III is loaded, test coil 1 will give the induction 60 degrees behind the centre of loaded limb coil 2, 50 degrees, coil 3, 40 degrees and so on to coil 6. When limb II-III is loaded, the curve from coil 1 shows the variation of induction at the centre of the loaded limb, coil 2 shows the variation of induction 10 degrees in advance of the centre and so on up to coil 6. When limb I-III is loaded, test coil 1 gives the variation of induction 120 degrees behind the centre of the loaded limb, test coil 2, 110 degrees behind and so on up to coil 6. Thus are obtained a series of eighteen curves, showing the instantaneous induction for every 10 degrees from 120 degrees behind the centre of the loaded limb to 50 degrees in advance of the centre as the armature rotates. The eighteen curves numbered I to XVIII, are shown on Plate 5. The origin of each curve is shifted 20 degrees to the right and $1\frac{1}{4}$ volts below that of the preceding curve for clearness.

From these exploration curves the instantaneous induction distribution for particular positions of the armature is easily found. Suppose that the centre of the loaded limb is on the line of commutation, which in all cases is 15 degrees from the point midway between the pole tips, as shown by line A B in Fig. 5, and that the distribution was desired for the limb in this position. The line of commutation is taken as reference line. It will be seen by reference to Fig. 4 that taking the zero point of curve VII gives the induction at the point where the centre of the loaded limb is at zero degrees; then if the reading is taken at 10 degrees on curve VIII, the amount of induction for 10 degrees in advance of the centre of the limb, in same position, is obtained. The induction for 10 degrees further will be represented by the reading for 20 degrees on curve IX and so on.

The series of readings for curves, Plate 6, were obtained in this manner, and show the instantaneous distribution of induction over the pole faces with one limb loaded in different angular positions.

Of course, the same curves might have been obtained directly, by measuring successively the electromotive force in each of a series of test coils evenly spaced for one particular position of the loaded limb or armature, but the above indirect method is easier of manipulation.

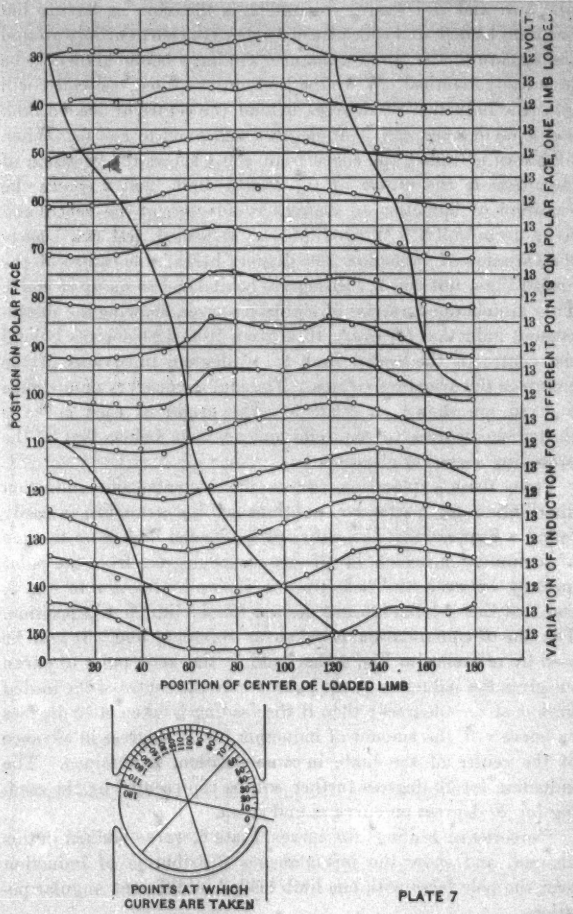
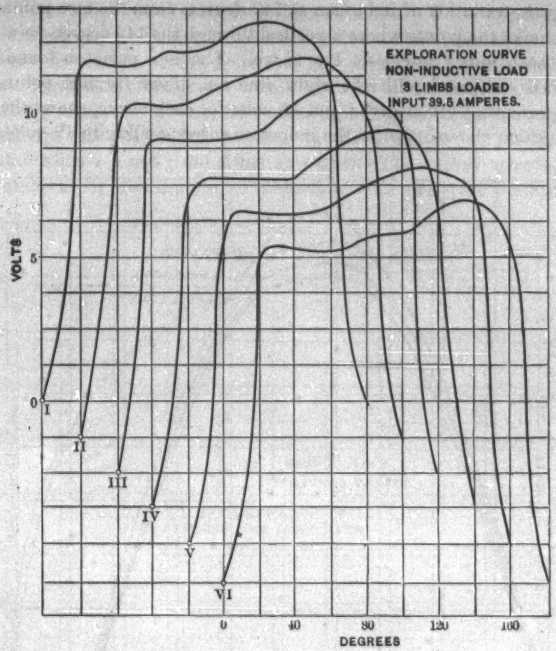


PLATE 7

The curves, Plate 7, show the variation of induction through particular points in the polar face as the loaded limb assumes different positions. These curves are obtained directly from the


EXPLORATION CURVE
NON-INDUCTIVE LOAD
3 LIMBS LOADED
INPUT 39.5 AMPERES.
VOLTS
10
5
0
I
II
III
IV
V
VI
0
40
80
120
160
DEGREES

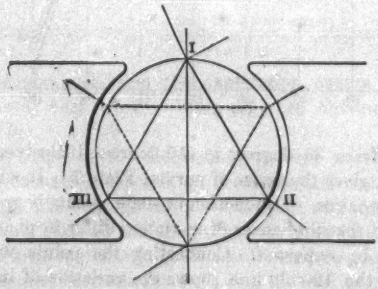

I
III
II

PLATE 8

curves, Plate 5. Suppose it is desired to draw a curve representing the variation of induction at 140 degrees from the zero point. Connect the points where a vertical through the 140 degree point of each curve intersects the curve. The new curve so found, when compared with the right line A B, drawn through points representing 140 degrees and 12 volts for each curve, shows the variation above or below the induction corresponding to 12 volts.

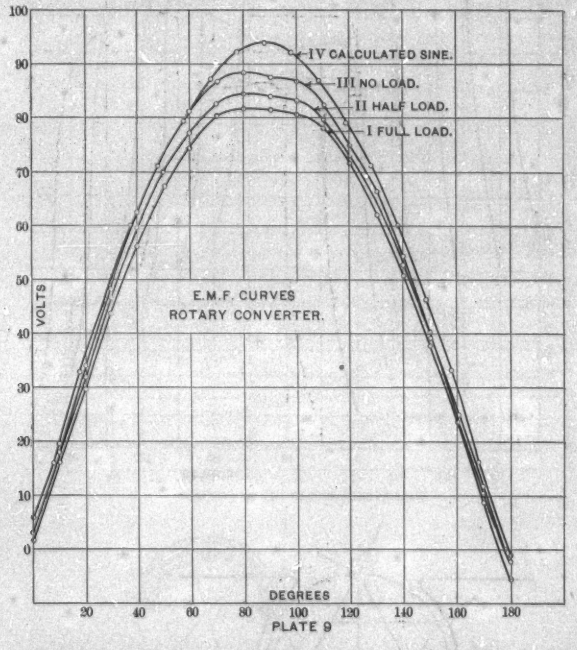


PLATE 9

Taking points from 30 degrees to 150 degrees, inclusive, and changing the axes, gives the series of curves, Plate 7. It will be noted, that the variation of induction at some points is greater than at others, and that the waves of variation differ in phase as of course would be expected. Connecting the points where these curves cross the 12-volt line shows the variation of induction at successive points in time and amount very nicely.

The exploration curves, Plate 8, were taken with all three limbs equally loaded with incandescent lamps. When one limb is loaded, any particular distribution of induction occurs twice in every revolution of the armature, but with three limbs loaded, this happens six times per revolution. In Plate 8, curve VI is exactly similar to curve I, and referring to Fig. 6, it will be seen that the distribution of currents in the armature will be the same when A B and C are either at N or P. The curves showing instantaneous distribution of induction with armature position

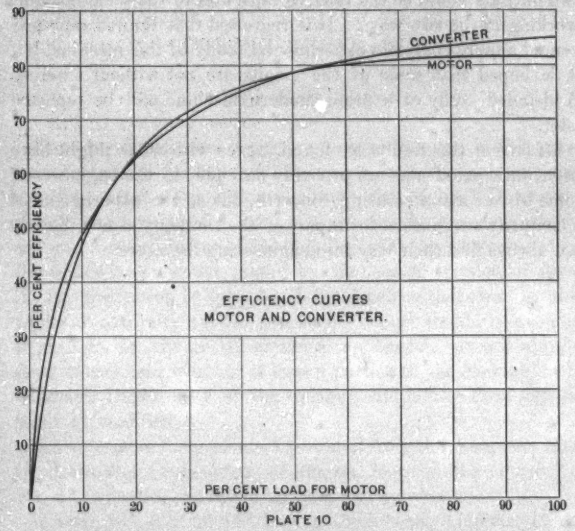


PLATE 10

can be obtained from the exploration curves in Plate 8 in the same way that curves, Plate 6, were obtained from curves, Plate 5.

The shape of the electromotive force curves taken from a rotary converter depends on the induction distribution. If the lines of force through the poles, air gap, and armature were uniform and parallel, the electromotive force in each turn of wire on the armature would be sinusoidal, and the electromotive force as measured between any leg being the sum of sine waves would also be sinusoidal, but the electromotive force curve we actually

get is the sum of a series of electromotive force curves similar to curves Plate 5, differing in phase by the conductor angle. On Plate 9 are shown electromotive force curves between legs for different loads. Curve I is for full load, curve II for half load and curve III for no load. Curve IV is a sine wave whose R. M. S. value is 67.4 volts. Plate 10 shows the efficiency curves for the machine as a motor and as a converter. If the load on the machine as a converter had been increased until the losses equalled the losses of the motor at full load, then the ratio of the two outputs would be the relative capacities of the same machine working in the two ways. It is regretted that limited time prevented a more complete experimental study of this machine, but it is hoped that some of the results are not without interest. A detailed study of a more modern machine will be reported later.

Of course the results as found, agree with what might have been anticipated and are probably not new to the engineers of some of our manufacturing concerns, but as the experiments of a company's engineers form part of the company assets, they do not always find their way into engineering literature.

A paper presented at the 14th General Meeting of the American Institute of Electrical Engineers, Eliot, Me., July 28th, 1897. Vice-President Steinmetz in the Chair.

THE ECONOMY AND UTILITY OF ELECTRICAL COOKING APPARATUS.

BY JOHN PRICE JACKSON.

The tests of electrical cooking apparatus detailed in this paper were made with the hope of obtaining a method of cooking that would be satisfactory with a minimum risk of fire. During the past winter a serious fire, which might readily have become disastrous, occurred in one of the buildings of the college with which the writer is connected, caused by the use of an alcohol stove. As this institution is lighted and furnished with power by electricity, it naturally was felt that such a danger should be avoided, if possible, by the use of electrical appliances. It was also desired to ascertain whether at least a portion of the cooking in the Woman's Department of the college could not be done satisfactorily by electricity.

To determine these points, I procured from the American Electrical Heating Corporation, of Boston, through the courtesy of Mr. J. E. Sayles, the following pieces of apparatus:

1 oven, $13'' \times 9'' \times 18''$, having three heats, 3, 10 and 17 amperes respectively.

3 stoves of 2, 4 and 5 amperes respectively.

2 flatirons of 1.5 and 6 amperes capacity.

1 broiler of 12 amperes capacity.

1 curling iron of $\frac{1}{2}$ ampere capacity.

The pressure used by these is 110 volts.

The stoves are round disks of iron, on the under side of which the heating wires are imbedded in a non-conducting, incombustible compound. The oven is a box, so thoroughly heat-insulated that the outside metal covering never reaches a tem-

perature uncomfortable to the hand. The broiler is made of a corrugated metal surface, slightly tipped from the horizontal, with a drip groove at the lower edge for catching the meat juices. The flatirons are similar in construction to the stoves, the larger one having a low current switch, which enables the operator to control the heat.

In all these appliances the heating coils are so arranged that the energy is largely concentrated at useful points. They are also supplied with supports and bases which will not conduct heat.

The efficiencies of the two larger stoves were obtained by heating two pounds of water to the boiling point and measuring the power supplied by a calibrated wattmeter. The cooking vessels used were ordinary stewing pans, with the bases nearly of the same size as the tops of the stoves. The efficiencies, considering the ratio between the amount of heat absorbed by the water and the amount received by the stoves were:

For the larger or No. 1, 48.9 per cent.

For the next size, " 2, 43.1 "

These efficiencies could be increased by having the pans made to fit the stoves exactly, and still further by carefully covering the pans, lids and exposed portions of the stoves with a non-conductor of heat.

When it is desired to boil water, the best plan is to place an immersion coil in a properly heat-insulated pot; such an arrangement should give an efficiency of from 90 to 100 per cent. We unluckily did not have such a coil at our disposal.

It was impossible to measure the cooking efficiency of the oven, but as it was merely warm on the outside after potatoes or bread had been baked and "done to a turn," the efficiency is high. In baking, the current was turned on and the oven allowed to heat for five minutes before the articles to be cooked were placed within, and the current was turned off from ten to twenty minutes before the baking was done, when the heat of the oven was sufficient to complete the operation. The broiler was manipulated in much the same manner, thus utilizing the greatest possible amount of heat. This electrical apparatus was used for several weeks in cooking most of the meals for a family of six.

The following table indicates the amount of cooking done for the first breakfast, dinner and supper, respectively, and may be taken as a fair average of the whole period.

All costs have been estimated on the basis of 10 cents per kilowatt hour, the average rate charged for residence electrical supply in a near-by town. The foods were not measured, as it was believed more desirable to determine whether in a long period of cooking the apparatus would prove satisfactory for a family of given size.

The largest stove is designated No. 1; the next size, No. 2; the third size, No. 3; the broiler, B and the oven, O.

BREAKFAST.

TIME.	UTENSILS.	FOOD.	WATTS.
6.55	No. 1, on	Rolled Oats	
6.55	2, on	Coffee	844
7.45	1, off		
7.45	B, on	Beefsteak	1500
7.55	2, off		1155
8.05	B, off		

Kilowatt Hours, 1.355 Cost, 11.46 cents.

DINNER.

10.51	No. O, on	Beef Roast }	
10.55		Potatoes }	1610
11.35		Pie }	
11.46	1, on	Asparagus	1990
12.05	O. off		
12.05	2, on	Coffee	1180
12.11	B, on	Toast for Aspar	2200
12.29	1, off		1835
12.32	B, off		
12.32	2, off		

Kilowatt Hours, 2.98 Cost, 29.8 cents.

SUPPER.

4.59	No. 1, on	Cocoa	630
5.15	2, on	Potato Cakes	1010
5.16	B, on	Omelet	2100
5.22	2, off		1700
5.26	B, off		
5.26	2, on		1130
5.43	2, off		640
5.44	1. off		

Kilowatt Hours, 8.39 Cost, 8.39 cents.

Four pies can be baked in the oven at an expenditure of .62 kilowatt hours and a cost of 6.2 cents or 2.05 cents per pie. Two large loaves of bread were baked with the current on the oven 50 minues, at an expenditure of 1.22 kilowatt hours, a cost of 12.2 cents or 6.1 cents per loaf. Four rather small-sized loaves could have been baked as readily. Biscuits with about the same expenditure of energy as in the case of pies. The broiler utilized

about the same amount of energy for all kinds of meat as indicated in the table. The cost of soup sufficient for the family was about 4.5 cents.

The result of the whole series of meals was a cost for electricity of 13.1 cents per meal. The heating of water for washing the dishes took an additional .35 of a kilowatt hour per meal, which raises the cost to 16.6 cents per meal.

To determine the relative cost of cooking with electricity and coal, the same foods were cooked on the No. 8 Othello coal stove ordinarily used by the family. The coal was carefully weighed. The results gave an average of 12.6 pounds per meal, which at $5.00 per ton gives a cost of 3.15 cents per meal.

The results show the cost of cooking by coal to be about 19 per cent of the cost of cooking by electricity.

Ironing was done for the same household a number of times. The heavy articles were done with the large iron; while for fancy dresses and light articles, the small iron was used. The average time taken was four hours, and the expenditure of energy in kilowatt hours was 2.27. This made the cost of the ironing 22.7 cents.

An equal number of tests was made using the coal range, the fuel being carefully weighed. For the same sized wash, the ironing took five hours, at a cost of 12.25 cents. This shows the cost of energy by the use of coal to be 54 per cent. of that by electricity.

The results of the cooking tests seem to indicate that for the usual cooking of a family for the whole year, the expense would be larger than would be ordinarily acceptable, notwithstanding the great advantages in other respects. However, in the following classes the utility of electrical cooking utensils should be great:

1. For light housekeeping, such as is practiced in small city apartments, and in many larger houses during the summer months, no other method presents so many desirable features. The dirt of coal and ashes, disagreeable gases and abnormal temperature due to a coal stove are entirely avoided. For such housekeeping a disk stove using 500 or 600 watts and a broiler using about 1200 watts would be sufficient for a small family and would cost from $20.00 to $30.00. A teakettle or immersion coil might be added at a cost of from $6.00 to $10.00. A special pair of wires would of necessity have to be run into the cooking room from

the house or apartment supply mains. The latter would ordinarily warrant the extra call that would be made upon them in this way. For similar purposes coal oil, gas or gasoline are frequently used, but with the inherent disadvantages of greater heat in the room, offensive odors, comparative uncleanliness and danger.

2. This form of cooking apparatus could be used with facility in boarding houses and restaurants for purposes which require an even temperature such as is needed in baking griddle cakes, boiling eggs, etc.

3. Where electricity is available, nothing could be more convenient than a small electrical stove, requiring 300 or 400 watts, for the many uses to which at present the alcohol flame is put, such as the afternoon tea-kettle, chafing-dish, toaster, etc. This use of alcohol is most unsafe as regards danger from fire, and could well be discarded for electricity, which is absolutely safe when properly installed, as well as being more convenient and better in other respects.

4. In the shop, the glue pot, solder pot, brazing iron, etc., can be heated advantageously by electricity and one of the most gratifying consequences of our experiments has been the decision to put such an equipment in our college shops.

5. The test of the electrical flatirons showed them more economical than the old form, when the saving of labor is taken into account. Not only is there a saving in time, but the severity of labor is much lessened. Our experience is that a laundress who has used an electrical iron would be exceedingly unwilling to go back to the old form.

A small flatiron of two or three amperes attached to the ordinary lighting fixture in a dressing room is a great convenience; and with the electric tea-kettle and curling-iron is destined to become essential in the modern home.

Concerning the question whether the use of electricity had proved satisfactory in its operations in the cooking tests described, the housekeeper in charge said: "The instruments were excellent in every respect. We were able to cook more rapidly, to keep the heat at just the right point, and could readily prevent over-cooking or under-cooking. While we were using electricity every dish was perfect. When I think of these advantages and of the cleanliness and convenience of the utensils, I sincerely hope that some of them at least may be retained in the house permanently."

The general results of the tests were of such a nature that the writer is warranted in the belief that if central station managers would more generally introduce exhibition equipments of these domestic utensils, a new call on their station capacity would develop, of which the larger proportion would be during the light load periods.

I wish to acknowledge my indebtedness to Mr. Rudolph F. Kelker, of Harrisburgh, Pa., for his valuable aid in carrying out the work briefly described above.

NOTICE.

Written discussions of the papers contained in this issue, if acceptable, will be printed in the October number, if received before October 15th.

The Secretary will esteem it a favor if his attention is called to any error in either papers or discussion, in order that they may be corrected before printing the sheets for the annual volume.

The INSTITUTE as a body is not responsible either for the statements made, or for the opinions expressed, in the TRANSACTIONS.

OBITUARY.

Frank Hayes Dorr, (associate member May 15th, 1894) was born in Somersworth, N. H., June 5th, 1869. The record of his life, though brief, is the story of earnest endeavor, of high aspiration and of large achievement.

He attended the public schools, and was graduated from the Somersworth High School in 1887. He then entered the Massachusetts Institute of Technology, and was graduated in June, 1891, receiving the degree of Bachelor of Science in Electrical Engineering.

The next month he enterered upon the expert course in electrical engineering in the Thomson-Houston electrical factories, in Lynn, Mass., remaining in the employ of the company a year. He was then transferred in 1892 to the Chicago office of the General Electric Company as an expert engineer.

During the World's Fair he had charge of the construction and operation of the two electric fountains. These fountains were the largest of the kind ever built, and in their construction were involved a great many new ideas and electrical and mechanical features, calling for the highest kind of engineering ability. There was perhaps nothing at the fair which excited so much interest and admiration as these fountains, and the result was very largely due to Mr. Dorr's splendid management of the intricate apparatus. He afterwards superintended the removal of one of these fountains to the Midwinter Exposition in California, and put it in position and operated it throughout the fair.

After this, Mr. Dorr returned to Chicago, and was continued with the General Electric Company on expert work in connection with multiphase apparatus, which necessitated frequent trips into many parts of the country, building and equipping electric

railroads and other enterprises. He was in charge of the installation of three-phase machinery at Austin, Texas, in connection with the water power plant owned by the city, and also had to do with various other important, difficult and intricate electrical installations.

It is possible that the sudden change of climate to which he was subjected, together with the alternations of outdoor and indoor work, prepared the way for the disease, consumption, which resulted in his death at Somersworth, January 8th, 1897.

Mr. Dorr was an electrical engineer of very high class and of exceptional ability, and had his life been spared, his name would have appeared frequently in connection with the advance in electrical development. He was a man of high integrity and unswerving fidelity. Possessing a sunny and genial nature, he had won the friendship of a large circle of friends, who sincerely mourn his loss.

S. E. W.

DIED.

LOZIER:—At New Brighton, Staten Island, August 26th, 1897, Arthur de la Montagnie, son of Jennie de la M. and the late Dr. A. W. Lozier, aged 23 years and 24 days. Mr. Lozier was elected an associate member of the Institute March 25th, 1896.

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RALPH W. POPE, Secretary.

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